BLAST-RESISTANT PANELS AND CONTAINERS

Field of the Invention

The present invention relates to blast-resistant devices, and more particularly to panels and containers used to suppress the blast force of an explosion.

Background of the Invention

With increased domestic and international terrorism, the need to protect people from the tools of terrorism has increased. Often, terrorists seek to attract attention to their cause by placing and detonating explosive devices in public areas. Such explosive devices may for example be delivered by mail, be placed in a container such as a suitcase and placed on an airplane or in an office lobby, or may simply be placed in a hidden area such as under a staircase.

When such an explosive device is discovered, it is often desired to place the device within a blast-resistant container such that the device may be transported to an area where it may be safely detonated, or such that the device may be detonated within the container itself. Alternatively, it may be desired to shield people from a possible explosion using blast-resistant panels, or by placing people within a blast-resistant room or container.

In the past, such blast-resistant panels and containers have generally been of a bulky and heavy design. An example of such a device is disclosed in U.S. Patent No. 4,055,247 (Benedick et al.), wherein protection from the blast force is afforded by thick steel walls.

More recently, lighter and less bulky blast-resistant containers have been developed. Such containers typically have

shells of sandwich construction, with relatively light outer and inner walls and a compressible material between the two walls to absorb the blast force. Examples of such blast-resistant containers are disclosed in U.S. Patent No. 4,889,258 (Yerushalmi), and in published U.K. Patent Application 2,262,798 A (Rowse et al.).

It has been discovered that such sandwich construction panels and containers often fail when the inner wall is ruptured by the blast force, allowing blast gases to escape through a small opening, concentrating the force of the blast gases on a small portion of the compressible material and ultimately on the outer wall. This problem is particularly acute when the compressible material is of honeycomb construction as the escaping blast gases simply pass through the holes in the honeycomb and impinge on the outer wall directly.

This problem is partly solved with respect to flat panels in Rowse et al. through use of corrugated or concertina shaped sheets embedded in the compressible material. However, such a construction is effective only in permitting expansion of the sheet in one direction - perpendicular to the corrugations, whereas the force of the blast is more effectively absorbed if the sheet is permitted to expand in two directions. Furthermore, the corrugated sheets result in complex construction, since the surfaces of the compressible material adjacent the corrugated sheets would need to be corrugated themselves to allow the compressible material to lie flush against the corrugated sheet.

Summary of the Invention

According to a broad aspect, the present invention provides a blast-resistant panel having a first layer of overlapping plates, a compressible second layer located

adjacent the first layer, and a third layer located adjacent the second layer, wherein upon detonation of an explosive located adjacent the first layer, the overlapping plates slide relative to one another allowing the first layer to compress the second layer without permitting substantial release of gases through the first layer, the second layer absorbing energy from the blast, and the third layer restricting substantial displacement of the second layer.

According to another aspect, the present invention provides a blast-resistant panel having a first layer of axially-slidable plates, a compressible second layer located adjacent the first layer, guiding ribs between the plates of the first layer to guide axial movement of the plates, said guiding ribs being shaped to substantially provide and maintain a seal with the plates during axial sliding of the plates and a third layer located adjacent the second layer, wherein upon detonation of an explosive located adjacent the first layer, the plates slide toward the third layer, guided by the guiding ribs, allowing the first layer to compress the second layer without permitting substantial release of gases through the first layer, the second layer absorbing energy from the blast, and the third layer restricting substantial displacement of the second layer.

According to a further aspect, the present invention provides a blast-resistant container having a substantially spheroid shell having a first layer of overlapping plates, a compressible second layer located adjacent the first layer and a third layer located adjacent the second layer, and a sealable door in the shell, wherein upon detonation of an explosive located adjacent the first layer, the overlapping plates of the first layer slide relative to one another allowing the first layer to compress the second layer without permitting

substantial release of gases through the first layer, the second layer absorbing energy from the blast, and the third layer restricting substantial displacement of the second layer.

According to a further aspect, the present invention provides a blast-resistant container having a substantially spheroid shell having a first layer of axially-slidable plates, a compressible second layer located adjacent the first layer, guiding ribs between the plates of the first layer to guide axial movement of the plates, said guiding ribs being shaped to substantially provide and maintain a seal with the plates during axial sliding of the plates, and a third layer located adjacent the second layer and a door in the shell, wherein upon detonation of an explosive located adjacent the first layer, the plates slide toward the third layer, guided by the guiding ribs, allowing the first layer to compress the second layer without permitting substantial release of gases through the first layer, the second layer absorbing energy from the blast, and the third layer restricting substantial displacement of the second layer.

The embodiments of the present invention comprising a container also contemplate a sampling / decontamination system for determining the presence of, and decontaminating at least one of chemical and biological agents within the container.

The embodiments of the present invention comprising a container also contemplate a door having a three-layer construction similar to that described above.

Advantageously, upon detonation of an explosive placed near the first layer of the blast-resistant panels and containers of the present invention, the first layer is permitted to move towards the third layer without substantial release of gases therethrough, thereby allowing the panels and

containers to more effectively absorb blast forces. Additionally, construction is simplified, particularly with respect to the embodiments of the present invention involving sliding plates, since the compressible second layer requires only minimal shaping to lie flush against the first layer.

Other objects, features and advantages will be apparent from the following detailed description taken in connection with the accompanying sheets of drawings.

Brief Description of the Drawings

Preferred embodiments of the invention will now be described with reference to the attached drawings in which:

Figure 1 is a front view of a blast-resistant container according to an embodiment of the invention;

Figure 2 is a top view of the blast-resistant container of Figure 1;

Figure 3 is a cross-sectional view of a portion of a shell of the blast-resistant container of Figure 1 marked as A in Figure 1;

Figure 4 is a front view of a first layer of the shell of the blast-resistant container of Figure 1;

Figure 5 is a top view of the first layer of the shell of the blast-resistant container of Figure 1;

Figure 6 is a top cross-sectional view of the blast-resistant container of Figure 1 taken at line B-B of Figure 1, in a door-open position - in this view the shell is schematically represented as a line;

Figure 7 is the top cross-sectional view of Figure 7 with the blast-resistant container in a door-closed position;

Figure 8 is a cross-sectional top view of a shell of another embodiment of the blast-resistant container of the present invention;

Figure 9 is a front view of a first layer of a shell of a further embodiment of the blast-resistant container of the present invention; and

Figure 10 is a schematic view of a sampling / decontamination system in accordance with a still further embodiment of the blast-resistant container of the present invention.

Detailed Description of the Drawings

A blast-resistant container 20 according to a preferred embodiment of the present invention is shown in Figure 1. As viewed from the exterior, the blast-resistant container 20 generally consists of a substantially spherical shell 22 with a door opening 24 defined by a door frame 25, a belly band 26, and a door motor 28.

The construction of the shell 22 is best seen in Figure 3 which is a cross-sectional view of a portion (identified as "A" in Figure 1) of the shell 22 of the blast-resistant container 20. The shell 22 generally consists of a first layer 30, a second layer 32 adjacent to and surrounding the first layer 30, and a third layer 34 adjacent to and surrounding the second layer 32. The shell 22 is shaped and sized to accommodate the most likely shapes and sizes of objects to be placed within the blast-resistant container 10. As noted previously, in the preferred embodiment, the shell 22 is spherical.

In the preferred embodiment, the first layer 30 consists of a plurality of adjacent and concentric spherical

sub-layers 40, one of which is depicted in Figures 4 and 5. The sub-layer 40 is constructed of a plurality of plates 36, 38 arranged in overlapping relationship to one another. These plates 36, 38 consist of main plates 36 and end plates 38. The main plates 36, are lune-shaped. These main plates 36 are placed in overlapping relationship with their apexes aligned, to form a sphere, as shown in Figures 4 and 5. The amount of overlap will depend upon the desired distance the first layer 30 is to expand upon detonation of an explosive device placed within the blast-resistant container 20. The two regions where the apexes of the main plates 36 are aligned are covered by the end plates 38 to further assist in providing a seal during expansion of the first layer 30.

When the plurality of sub-layers 40 are assembled to form the first layer 30, the sub-layers 40 are preferably rotated such that the apexes of the main plates 36 of any one sub-layer will not be aligned with the apexes of the main plates 36 of any other sub-layer. The plates 36, 38 are preferably constructed of a material able to withstand the heat created by the explosion without significant structural degradation, and are thin enough such that they will bend slightly to substantially maintain a seal during expansion of the first layer 30. In the preferred embodiment, the first layer 20 is constructed of steel, has a nominal diameter of 40 inches, the overlap between adjacent main plates 36 is 1″ and the thickness of the plates 36, 38 is 1/16″. The plates 36, 38 of each sub-layer 40 of the first layer 30 are preferably initially bonded to one another, and each sub-layer 40 of the first layer 30 is likewise initially bonded to each adjacent other sub-layer 40, such as by spot welding, to ease construction of the shell 22, and to maintain the configuration of the plates prior to detonation. However, the manner in which the plates 36, 38 are attached should be sufficiently

weak to allow them to slide relative to one another upon detonation of an explosive device within the shell 22.

The second layer 32 is also spherical in shape, lies immediately outside the first layer 30, and is constructed of a compressible material. Preferably, the second layer 32 is constructed of a material able to withstand the heat created by the explosion without significant structural degradation, and has a predictable force/crush profile. The thickness and compressibility of the second layer 32 will depend on the blast force sought to be absorbed by the container, and in the preferred embodiment, the second layer 32 is constructed of a 1″ thick layer of 325 psi crush strength aluminum honeycomb.

In the preferred embodiment, the purpose of the third layer 34 is to simply resist expansion of the second layer 32. Thus, it may be lightweight. In the preferred embodiment, the third layer 34 is 1/8″ thick aluminum.

To construct the shell 22 of the preferred embodiment container 20, a first sub-layer 40 of the first layer 30 is formed by spot-welding each of the plates 36, 38 in place. Each successive sub-layer 40 of the first layer 30 is then formed, being sure not to align the apexes of the main plates 36 of any two sub-layers 40, again spot-welding the plates 36, 38 in place until the first layer 30 has been fully assembled.

Each of the second layer 32 and third layer 34 is initially formed having bottom and top halves. During construction, the bottom half of the second layer 32 is placed into the bottom half of the third layer 34. The assembled first layer 30 is then placed into the bottom half of the second layer 32, the top half of the second layer 32 is placed overtop the assembled first layer 30, and then the top half of

the third layer 34 is placed overtop the top half of the second layer.

The two halves of the third layer 34 are then welded to one another, the belly band 26 is placed overtop this weld, and is itself welded to the third layer 34 to ensure that the two halves of the third layer 34 do not come apart during detonation of an explosive device within the shell 22.

The explosive device is placed into the shell 22 through the door opening 24 as defined by the door frame 25 having a curved interior profile. Once inside the shell 22, the explosive device is placed on a rotating tray 42 supported within the shell 22, as shown in Figure 6. The rotating tray 42 has attached thereto a door 44. The door 44 has an exterior surface which is curved so as to closely fit the curved interior profile of the door frame 25 when the tray 42 is rotated to its door-closed position as shown in Figure 7. The door 44 is attached to the tray 42 by way of telescoping rods 46 such that when the tray 42 is rotated into its door-closed position as shown in Figure 7, the door 44 may be moved away from the tray 42 so as to seal against the door frame 25, sealing the door opening 24. The movement of the door 44 away from the tray may be by means of any of a number of well-known mechanisms, resilient means such as a spring for example, or through hydraulic cylinders which either push the door 44 out from the inside of the shell 22, or pull the door 44 out from outside the shell 22.

In the preferred embodiment, the door 44 has a three-layer construction similar to that of the shell 22. In particular, the door has a first interior layer 44a which in this case is not a series of sliding plates but is a unitary plate, a second layer 44b of the same honeycomb material as for the second layer 32 of the shell 22, and a third layer 44c

which again may be of a lightweight material. The door 44 also has a guide collar 47a along its periphery to guide the movement of the first layer 44a and also to shield the second layer 44b from blast forces. The three-layer construction of the door 44 allows it to absorb blast forces in a manner similar to that of the shell 22.

The interface between the door 44 and the door frame 25 is formed such that when the door 44 is moved away from the tray 42, a seal is formed between the door 44 and the door frame 25. In the preferred embodiment, this seal is formed by placing an elastomeric gasket 45 in a groove 45a formed in a rim 47 on the periphery of the third layer 44c of the door 44, which elastomeric gasket 45 and groove 45a mates with the inner surface of the door frame 25. The groove 45a in the rim 47 is deeper than the depth required to contain the elastomeric gasket 45 to provide protection to the elastomeric gasket 45 from blast forces.

The rotation of the tray 42 between its door-open and door-closed positions is controlled by a motor 28 mounted above the container 20, which is connected to the tray 42 through a control rod 46 which travels through the shell 22 and is attached to the tray 42. The entry of the control rod 46 through the shell 22 is sealed by using a sealing cap for example. The motor is controlled by a button (not shown) mounted to the exterior of the container 20.

In use, when a suspected explosive device (not shown) has been located in a public area, the blast-resistant container 20 is moved to its vicinity. Transportation of the blast-resistant container 20 may be facilitated by the use of, for example, handles (not shown) welded to the exterior of the shell 22, or by mounting the container 20 onto a trailer (not shown). The container 20 may be put into place by specialized

personnel, or by using a robot. All controls required to transport the container 20 and to operate the door motor are shaped and sized to facilitate manipulation by a robot.

Once the blast-resistant container 20 has been set down, the door 34 is opened if necessary, by pressing the button which controls the door motor 28. The explosive device is then picked up, placed through the door opening 24, and set on the tray 42 inside the shell 22. The button is then depressed, causing the tray 42 to rotate bringing the door 44 into alignment with the door frame 25, and then the door 44 is pressed against the door frame 25 through one of the means described above so as to create a seal. At this point the explosive device is fully sealed within the blast-resistant container 20. The blast-resistant container 20 is transported to another location for safe detonation of the explosive device.

Should the explosive device detonate within the blast-resistant container 20, the blast force will first strike the first layer 30 of the shell 22. Because the first layer 30 is substantially sealed, the blast will force the first layer outward, causing any bond between the plates 36, 38 to break. The plates 36, 38 of the first layer 30 are then free to move relative to each other and indeed do so, allowing the first layer 30 to expand. As mentioned above, during expansion of the first layer 30, the plates 36, 38 are sufficiently thin such that they will bend and conform to the new shape of the first layer to substantially maintain a seal, and to prevent significant escape of blast gases through the first layer 30. The rate and degree of expansion of the first layer 30 is controlled by the second layer 32. As the first layer 30 expands, force is imparted onto the compressible material of the second layer 32. Because expansion of the second layer 32

itself is prevented by the third layer 34, the second layer 32 compresses, absorbing and dissipating the energy of the blast. Once the compression-resistance of the second layer 32 exceeds the force exerted by the dissipating blast energy, the first layer 30 will decelerate and ultimately cease expanding, and the blast will have been contained.

An alternative configuration of a shell 22 of an embodiment of the present invention is shown in Figure 8. Figure 8 is a cross-sectional top view of the shell 22 of an alternative blast-resistant container. In this configuration, the lune-shaped main plates 36 do not overlap each other. Instead, they are separated by guide ribs 48. The sides of the two guide ribs 48 against which each main plate 36 abuts are parallel, such that the main plate 36 can slide axially outward while still substantially maintaining a seal in the first layer 30. Thus, again, the first layer 30 is permitted to expand while still substantially maintaining a seal.

Figure 10 is a schematic view of a sampling / decontamination system 50 which may optionally be incorporated into the preferred embodiment of the blast-resistant container 20 of the present invention for determining whether an explosive device sealed within the blast-resistant container 20 contains chemical or biological agents, and for decontaminating any such agents.

The sampling / decontamination system 50 generally consists of a sensor 52, a pump 54, a first sensing valve 56, an auxiliary inlet valve 58, inlet nozzles 60, an outlet 62, a second sensing valve 64 and an auxiliary outlet valve 66.

In the sampling mode, the auxiliary inlet valve 58 and auxiliary outlet valve 66 are closed, the first sensing valve 56 and second sensing valve 64 are open, and the pump 54

is operated to force a flow of air through the inlet nozzles 60 which are located in the first layer 32 of the shell 30. Air is then drawn out through the outlet 62 which is also located in the first layer 32 of the shell 30 at a location preferably diametrically opposite to the inlet nozzles 60. This sampled air is then drawn into the sensor 52 where a determination is made as to whether the explosive device contained within the blast-resistant container 20 possesses chemical or biological agents.

If any such agents are found, the first sensor valve 56 and second sensor valve 64 are closed. A line to a suitable decontamination fluid is then connected to the auxiliary inlet valve. This decontamination fluid may be under pressure, or it may be pumped into the system. The auxiliary inlet valve 58 and auxiliary outlet valve 66 are then opened allowing the decontamination fluid to be sprayed into the interior of the blast-resistant container 20 and onto the explosive device through the inlet nozzles 60. Effluent is drawn out of the blast-resistant container through the outlet 62 and is discarded through the auxiliary outlet valve 66. Optionally, the air within the blast-resistant container 20 may then be sampled again using the procedure described in the preceding paragraph to assess the effectiveness of the decontamination.

Preferably, the sampling / decontamination system 50 described above is automated and controlled using a computer to facilitate the operation of the system.

Although the preferred embodiment of the present invention has been described above as a blast-resistant container, it is to be understood that the present invention also contemplates a blast-resistant panel comprising a portion of the shell 22 described above. Such a panel may be any shape, curved in one

direction, flat, domed inwardly or domed outwardly, for example.

Although the shell 12 of the blast-resistant container 10 of the present invention has been described as a sphere, it is to be understood that other spheroid shapes are contemplated, elongated spheres and obrounds, for example. A suitable configuration of the first layer 30 of an obround shell is shown in Figure 9.

Although the shell 22 of the blast-resistant container 20 of the present invention has been described as having the first layer 30 on the inside and the third layer 34 on the outside to protect against an explosive device placed within the blast-resistant container 20, it is to be understood that the first layer 30 may be located on the outside and the third layer 34 on the inside to protect the contents of the blast-resistant container 30 from a blast occurring outside the container 30. Thus, a large container 30 may be used to protect persons placed within the container 30 from a blast occurring outside the container 30.

Although the second layer 32 has been described above as being of honeycomb construction, it is to be understood that the second layer may be of any suitable compressible construction, closed-cell foam or springs, for example.

Although the main plates 36 of the first layer 30 have been described above as being lune-shaped, it is to be understood that other shapes may be used, curved triangles or rhombi for example. Additionally, although the number of main plates 36 of the first layer 30 has been described above as being 8, any suitable number of main plates 36 may be used, 4 for example.

Although the door 44 and tray 42 mechanism has been described in detail above, it is to be understood that any suitable door mechanism may be used.

Numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practised otherwise than as specifically described herein.